APPENDIX B

Hydrologic Analysis

FLOOD NEUTRAL HYDRAULIC ANALYSIS FOR THE NICOLAUS AND SINGH PROPERTIES

SACRAMENTO RIVER, RM 194-195

December 12, 2007

Prepared For:

The Nature Conservancy
Protecting nature. Preserving life.

AYRES ASSOCIATES

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Ayres Associates Project Number: 33-0563.00

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1.0 INTRODUCTION

1.1 General

This report summarizes the findings of a 2-dimensional hydraulic analysis on the Sacramento River from approximate river mile (RM) 194 to RM 195 (see **Figure 1)**. This report was prepared to assist The Nature Conservancy (TNC) in analyzing of the hydraulic effects of riparian restoration and the removal of several small berms along Mud Creek within the Sacramento River floodplain.

To determine the hydraulic effects of these changes on the floodplain of the river, an existing 2-dimensional (2D) hydraulic model was modified and used. The previous two-dimensional model was developed for TNC to analyze levee setback options and restoration (Ayres Associates, 2002).

The riparian restoration areas and the berms are located on the left side of the Sacramento River floodplain at approximately RM 194 – 195 as shown in **Figure 2**. In Figure 2, the land use change areas are outlined, and the yellow lines show the locations of the berms. The project area consists of two areas, the northern area is known as the Nicolaus Planting Zone, and the southern area is the Singh Planting Zone.

1.2 Purpose and Scope

The purpose of this project was to use an existing two-dimensional hydraulic model of the 29 mile reach of the Sacramento River between RM 183 and RM 212 to evaluate the hydraulic effects of habitat restoration and berm removal. This modeling was initially developed and calibrated for the J-levee project. The model was the extended and re-calibrated for the U.S. Army Corps of Engineers project (USACE). The model limits and project area are shown in Figure 1. The project was accomplished as laid out in the scope items listed below.

- Develop and calibrate the 2-D hydraulic model to the 1995 Flood Event with the updated land use map (2006). Based on the previous 2-D hydraulic model developed by Ayres Associates in 2002, the updated model was modified with 2006 year land use.

- Develop an existing condition hydraulic model – This hydraulic model simulated the 1995 flood flow using post-January 1995 topography, river configuration and 2006 land use.

- Proposed alternative hydraulic model run – This hydraulic simulation analyzed the impacts of the potential land use changes and the removal of berms on two parcels in conservation ownership in the reach between RM 194 and RM 195.

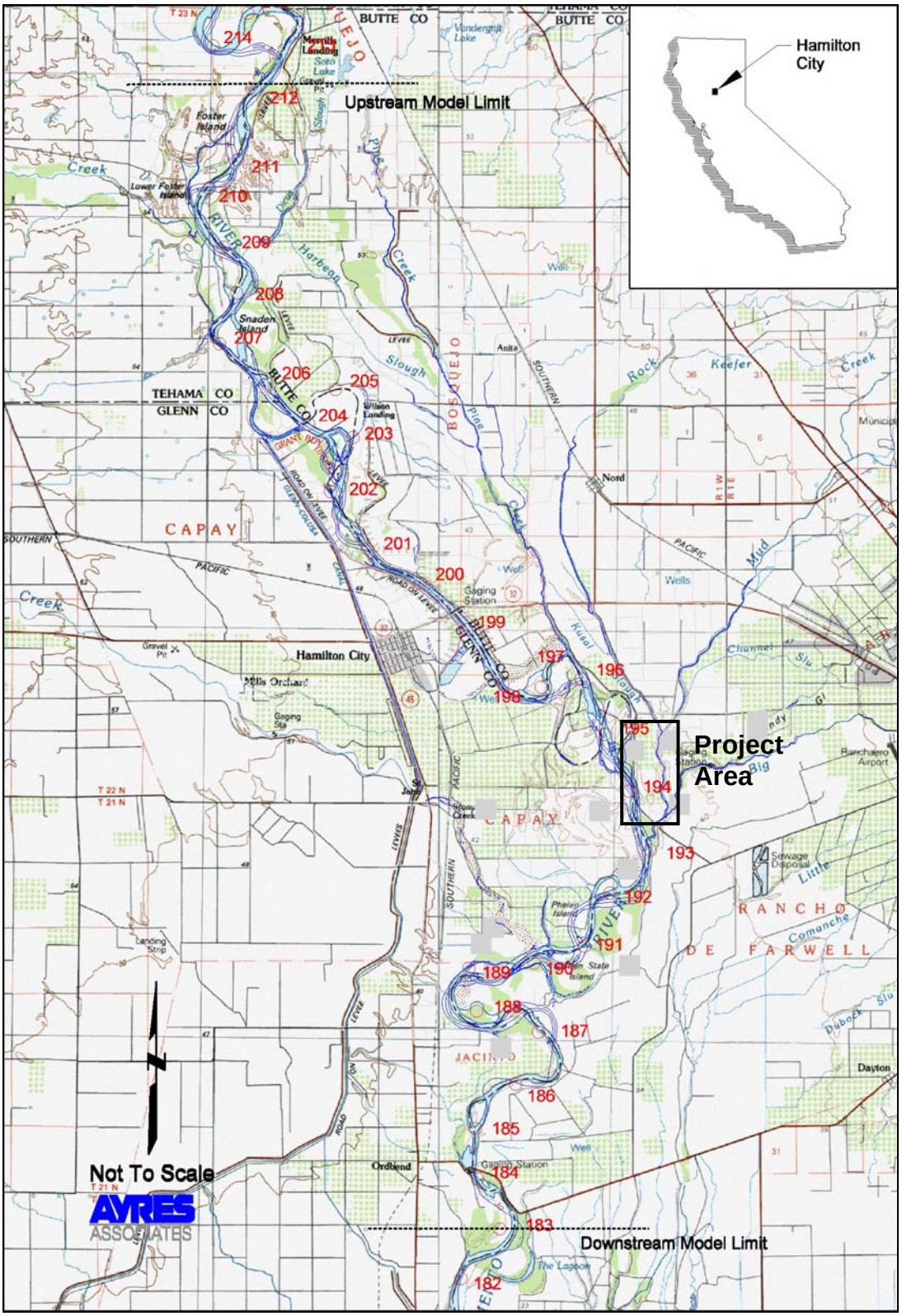


Figure 1. Location Map showing project area

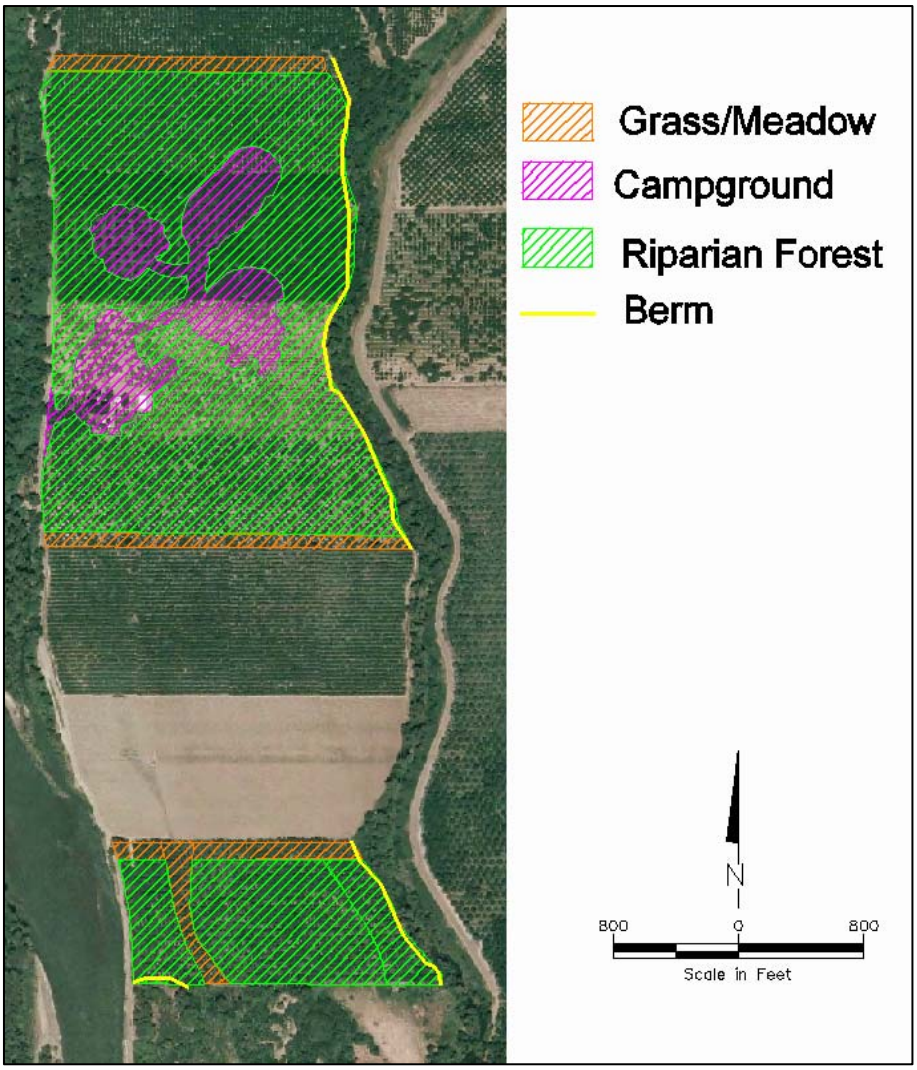


Figure 2. Project Area showing Proposed Habitat Restorations

1.3 Acknowledgements

This analysis was authorized by The Nature Conservancy (TNC) through the Sacramento River Projects office in Chico, California. The point of contact for TNC is Mr. Ryan Luster in Chico, California. The hydraulic modeling was conducted by the Sacramento office of Ayres Associates under the direction of Mr. Thomas W. Smith, PE, GE.

2.0 TWO-DIMENSIONAL HYDRAULIC MODEL RUNS

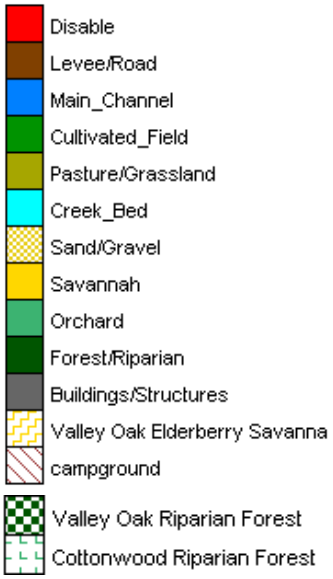
2.1 Existing Condition

The existing condition hydraulic model represents the land use in 2006 (based on aerials developed by the U.S. Department of Agriculture) and the river configuration that existed following the 1995 flood events. The land use in the project area is shown in **Figure 3**. The model uses the topographic mapping data developed for USACE following the 1997 flood event. This run will serve as a baseline for comparison to the with-project condition.

2.2 With-Project Condition

The with-project condition model incorporates proposed land use changes within two conservation ownership parcels (see **Figure 4**). In the Nicolaus Planting Zone, the land is currently covered by orchard, and will be converted to campground and forest, with a grassland buffer for the with-project condition. In the Singh Planting Zone, the proposed land use change is from orchard to mostly riparian forest, with a grass buffer at the north edge, and a meadow flow through. The rest of the model has the same land use for both the existing condition and the with-project condition.

The with-project condition model also removes the berms along the right bank of the Mud Creek, in the Sacramento River floodplain near RM 194, and the southern boundary of the Singh property. These berms are shown in Figure 2. The sizes and locations of berms were field verified by Ayres Associates in May 2007.



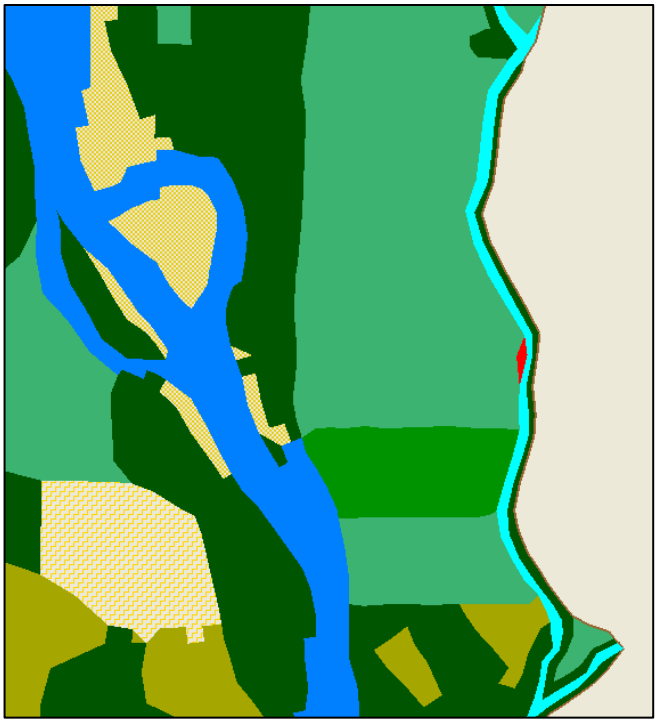


Figure 3. Existing Conditions Land Use

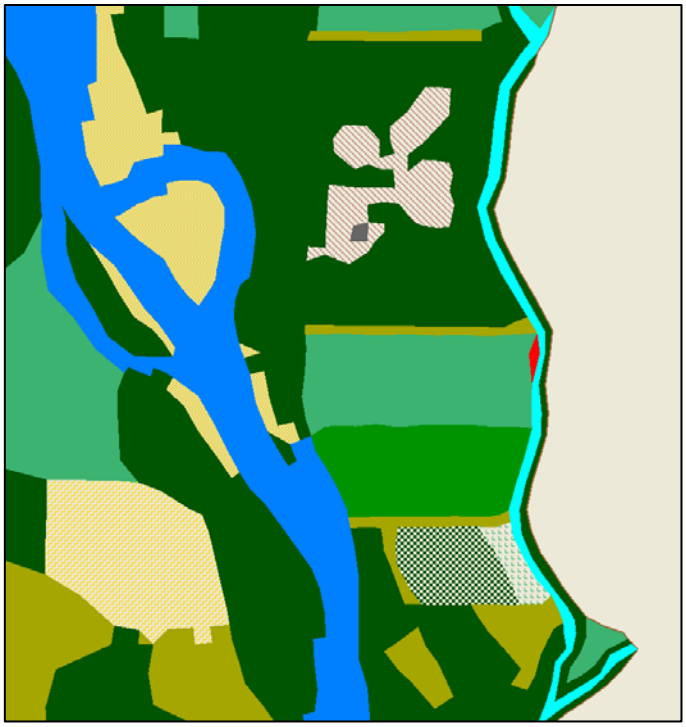


Figure 4. With-Project Land Use

3.0 HYDRAULIC MODELING

3.1 General

The 2-dimensional hydraulic modeling tool used for this project was the RMA-2V program, maintained and distributed by the USACE and modified by Ayres Associates. The program has been used extensively for similar projects on the Sacramento River and has proven to be an effective model for representing river flow conditions. The Surface-Water Modeling System (SMS) version 9.2 pre- and post-processor was used to develop the model geometry file and to view model results.

3.2 Model development

The geometric definition of the project reach is given in the form of a finite element network of triangular and quadrilateral elements, known as a mesh, as shown in **Figure 5**. The elements were sized and oriented to represent hydraulic features, breaklines, structures, and topographic changes. Each element contains corner and mid-side nodes, which represent points in space (X, Y, Z) and define the topography of the project reach. These nodes were laid out using topographic mapping and aerial photography as a reference for element size and orientation. Elevation values were assigned to the nodes using a digital terrain model of the river reach.

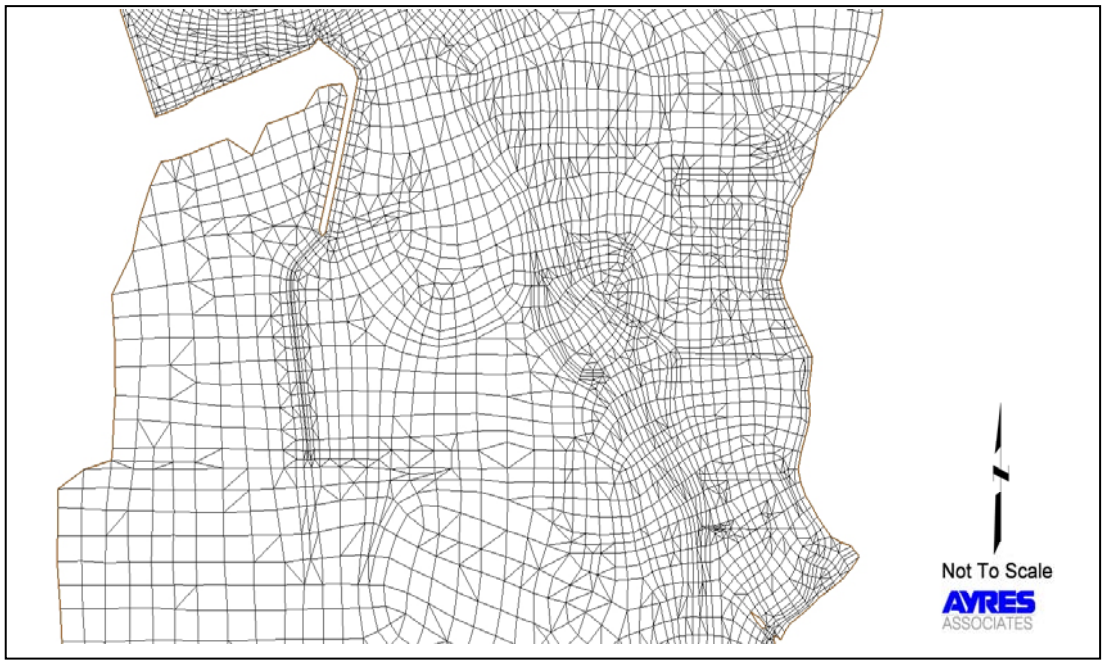


Figure 5. Plan view of the Finite Element Mesh

3.3 Material Roughness

Material types were assigned to each element based on land use and roughness characteristics. The land uses are represented in the model by Manning's roughness coefficients. The material types were assigned to each of the elements in the finite element mesh using 2006 aerial photograph. A field visit was also made to confirm land usage. For each material type, a Manning's roughness coefficient (n value) was assigned to represent a roughness type. These values were determined primarily from the previous modeling effort, and originally were derived using standard engineering protocols and references. Material types and corresponding Manning's n values used in the model are listed in **Table 1**. The land uses for the existing and with-project condition is shown in Figures 3 and 4. The material roughness of the campground is between Valley Oak Elderberry Savannah and Scrub. Therefore, the Manning's n value of campground is determined as the average n of those two materials.

Table 1. Manning's Roughness Coefficients

Landscape Description	Manning's Roughness Coefficients
Levee/Road	0.025
Main Channel	0.035
Cultivated Field	0.035
Pasture/Grassland	0.035
Creek Bed	0.035
Pine Creek Bed	0.035
Sand/Gravel	0.04
Stony Creek Bed	0.04
Savannah	0.05
Scrub	0.10
Orchard	0.15
Forest/Riparian	0.16
Buildings/Structures	0.20
Valley Oak Woodland	0.05
Valley Oak Elderberry Savanna	0.12
Valley Oak Riparian Forest	0.15
Cottonwood Riparian Forest	0.16
Campground	0.11

3.4 Boundary Conditions

The hydraulic model for this study extends from River Mile (RM) 212 at the upstream end to RM 183 at the downstream end, as shown in Figure 3. The RMA-2 program requires input parameters for the upstream and downstream ends of the model. The upstream flow data used for this model was the peak flow data from the January 1995 flood event published by USGS. Two inflows enter the simulation field, 170,000 cfs from Sacramento River, and 15,000 cfs from Stony Creek.

Downstream water surface elevation boundary conditions were referenced from previous 2-dimensional modeling conducted for the Butte Basin reach of the Sacramento River. The water surface elevation assigned to the downstream end of the model was 113.1 ft

3.5 Calibration

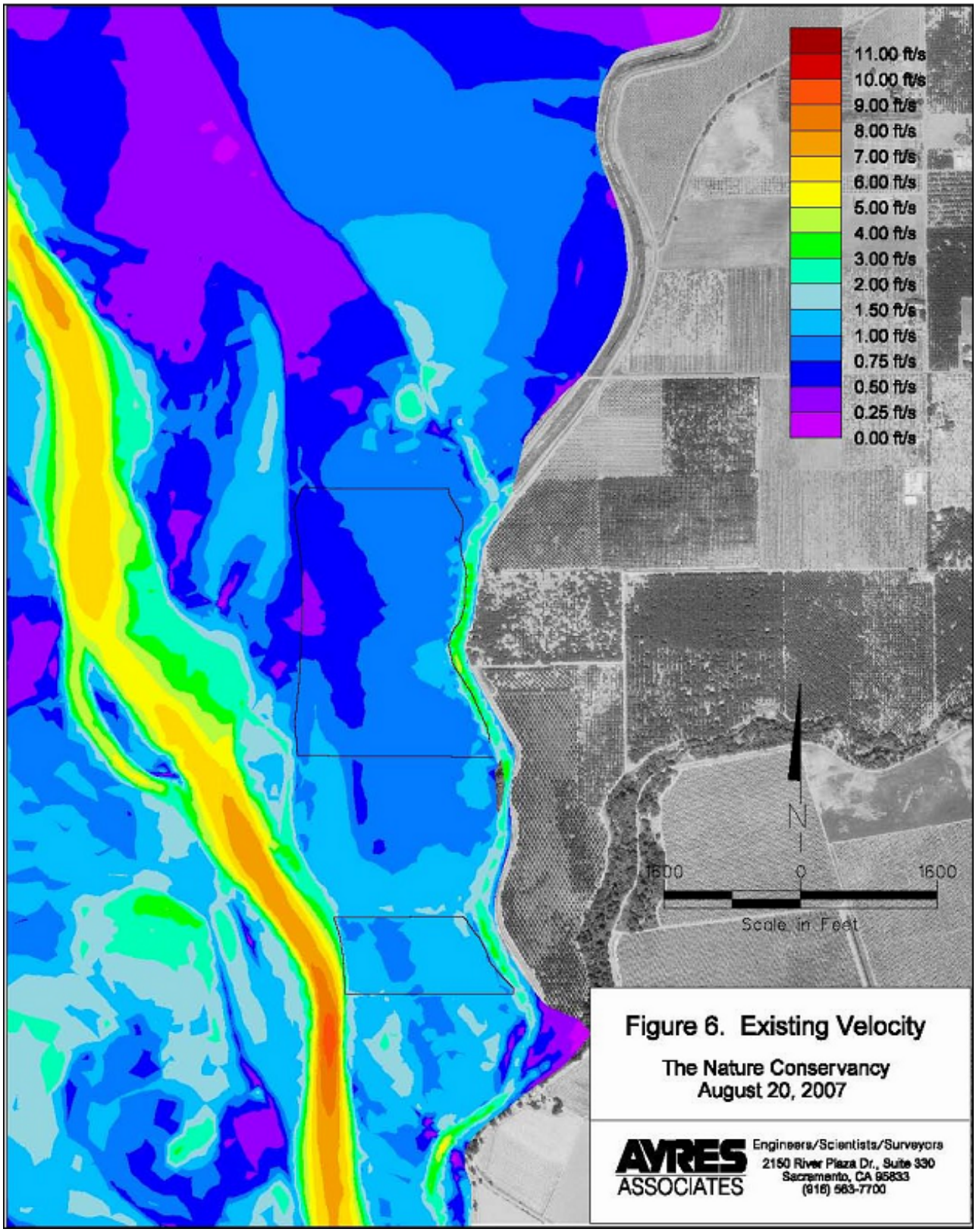
Two calibrations were performed by the previous studies, one for the initial J-levee project to a historic flood flow and again for the USACE project to a more recent flow event. The model used in this project is the latest version after calibration.

4.0 HYDRAULIC MODELING RESULTS

The velocity contours for the existing condition and the with-project condition are shown in **Figures 6** and **7**, respectively. The velocity differential plot is shown in **Figure 8**. The velocity differential equals the existing condition values subtracting from the with-project condition values. The velocity contours show that the velocity is between 0.0 ft/s and 3.5 ft/s in the project areas for both the existing condition and the with-project condition.

For the with-project condition, the land use change causes slight velocity increases. The largest velocity increase is 2.5 ft/s and is located in the meadow flow through passage in the Singh property. The existing velocity in that area is below 1.0 ft/s, and as long as the passageway remains vegetated, this increase should not have any harmful effects. There are increases adjacent to Mud Creek of up to 0.95 ft/s (from 1.8 ft/s to 2.75 ft/s). The grass buffers cause an increase on the west side of the properties, with the greatest increase being 1.1 ft/s (from 1.3 ft/s to 2.4 ft/s). The removal of the berm from the Singh property causes an increase in that area of up to 1.34 ft/s (from 1.55 ft/s to 2.89 ft/s) and also slightly reduces the velocity in the adjacent Mud Creek. Velocity vector plots for existing and with project condition are shown in **Figures 9** and **10**. These do not show any significant change in the flow path of the river and floodplain.

The water depth plots for the existing condition and the with-project condition are shown in **Figure 11** and **12**, respectively. The water surface differential plot is shown in **Figure 13**. The water surface elevation differential shows an increase within the Singh Planting Zone of roughly 0.10 ft. A decrease of 0.10 ft occurs on an adjacent property immediately upstream of Nicolaus.


11.00 ft/s
10.00 ft/s
9.00 ft/s
8.00 ft/s
7.00 ft/s
6.00 ft/s
5.00 ft/s
4.00 ft/s
3.00 ft/s
2.00 ft/s
1.50 ft/s
1.00 ft/s
0.75 ft/s
0.50 ft/s
0.25 ft/s
0.00 ft/s
N
1600
0
1600
Scale in Feet
Figure 6. Existing Velocity
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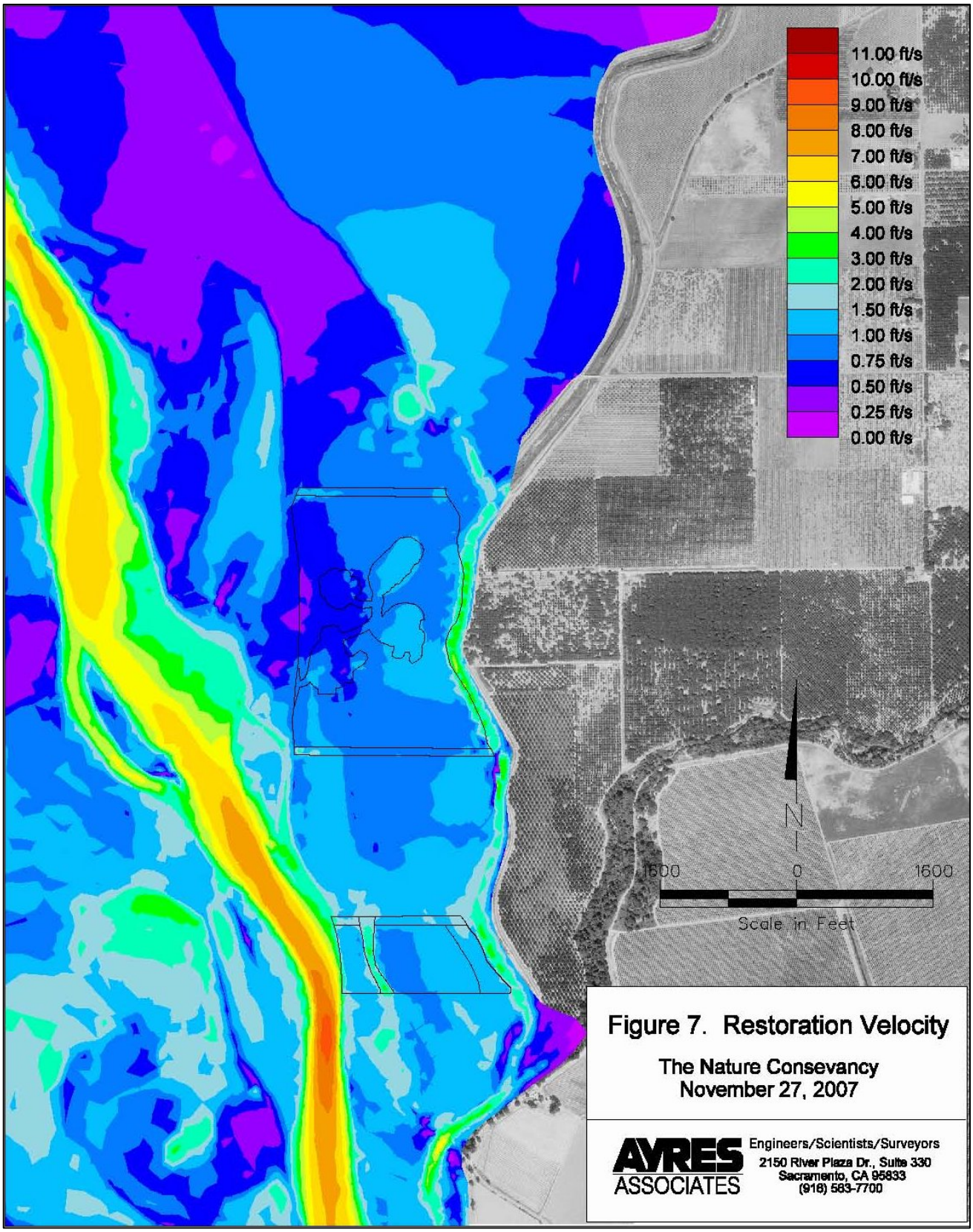

Figure 7. Restoration Velocity

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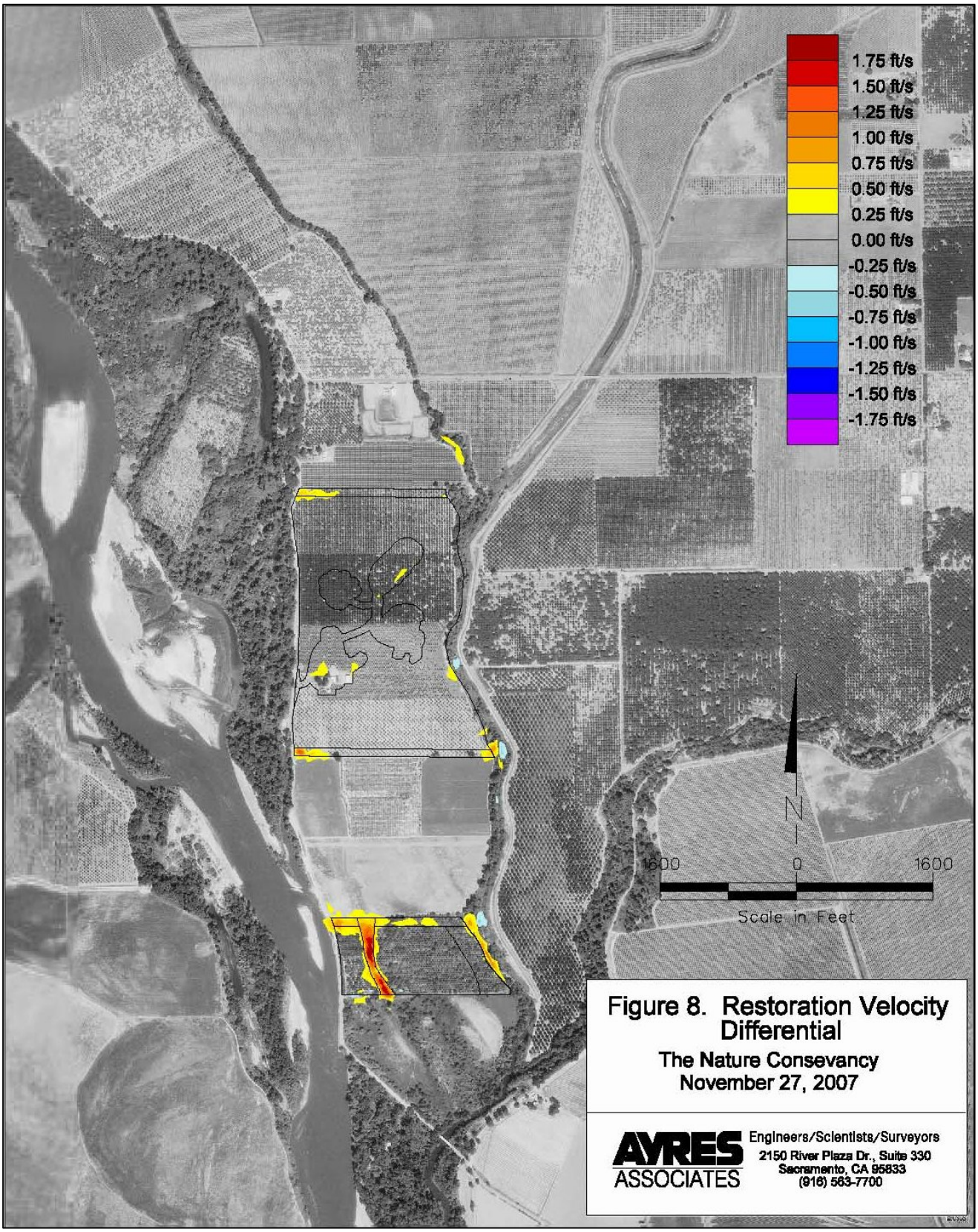
1.75 ft/s
1.50 ft/s
1.25 ft/s
1.00 ft/s
0.75 ft/s
0.50 ft/s
0.25 ft/s
0.00 ft/s
-0.25 ft/s
-0.50 ft/s
-0.75 ft/s
-1.00 ft/s
-1.25 ft/s
-1.50 ft/s
-1.75 ft/s
N
1600
0
1600
Scale in Feet
Figure 8. Restoration Velocity Differential
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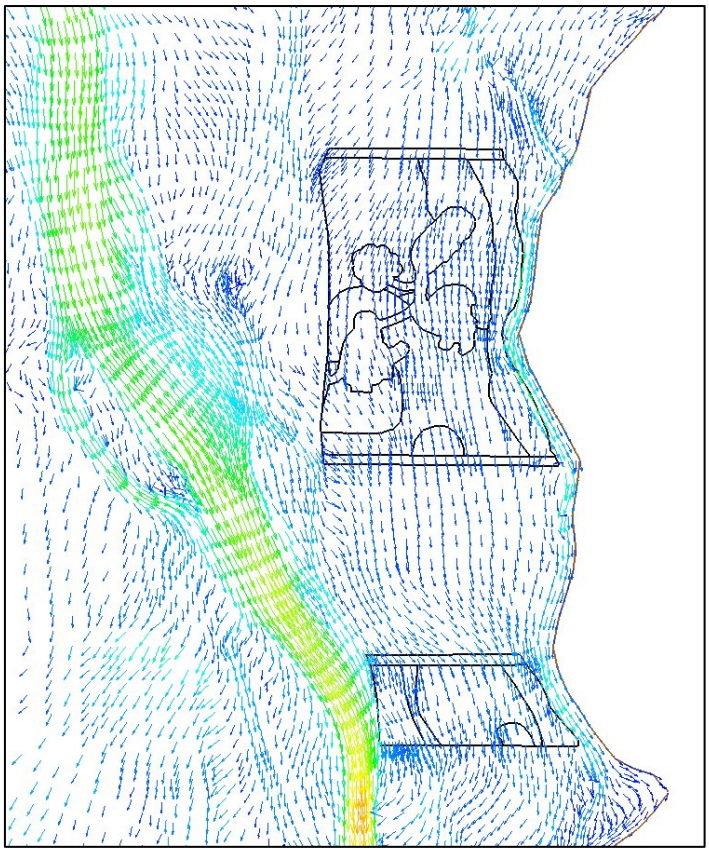


Figure 9. Existing Conditions Velocity Vectors

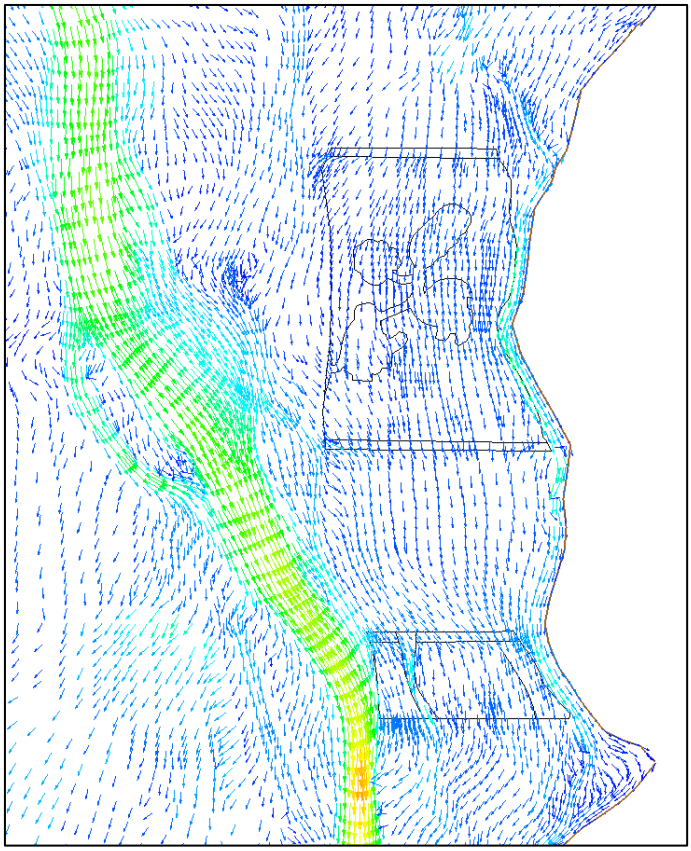
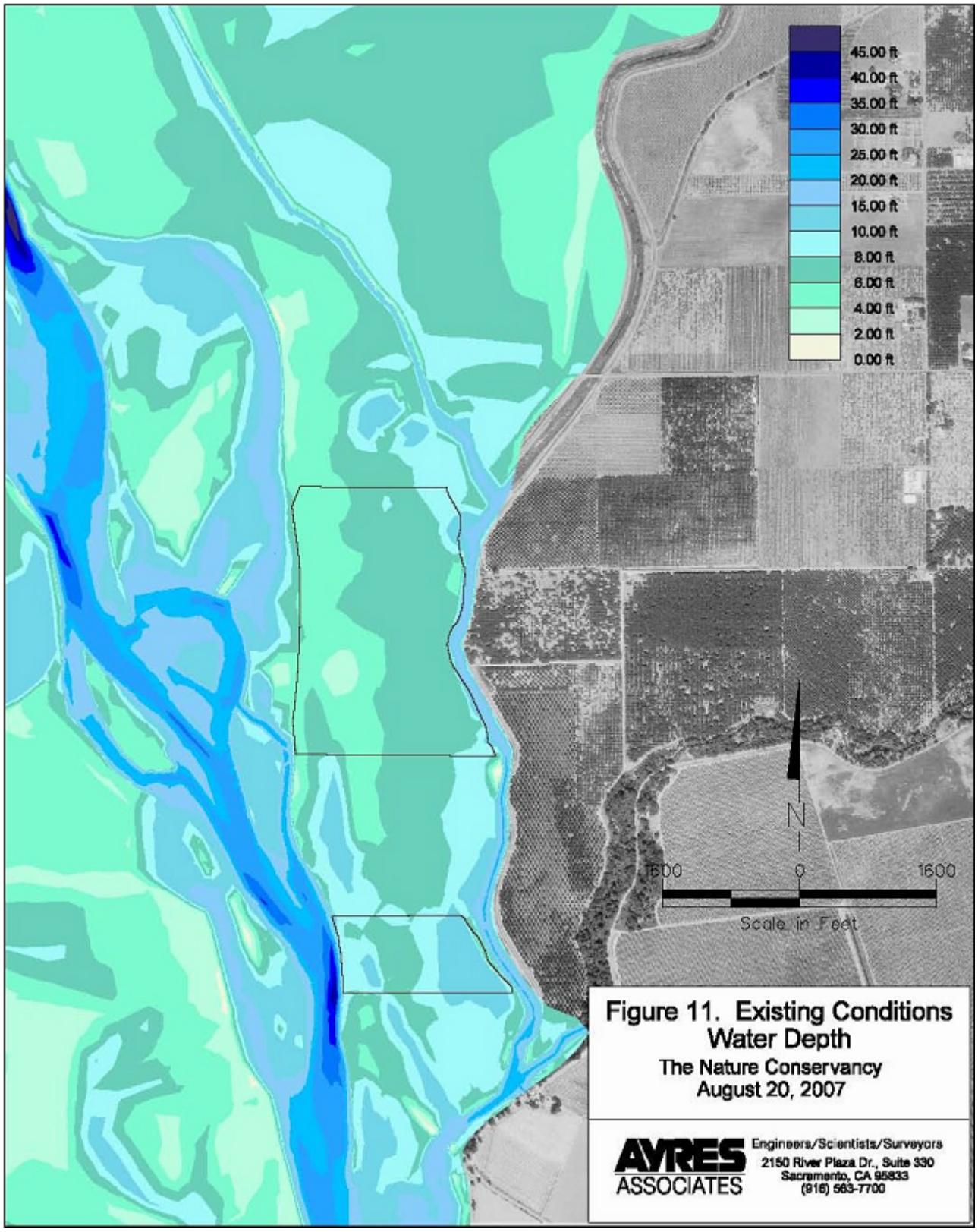


Figure 10. With Project Conditions Velocity Vectors


45.00 ft
40.00 ft
35.00 ft
30.00 ft
25.00 ft
20.00 ft
15.00 ft
10.00 ft
8.00 ft
6.00 ft
4.00 ft
2.00 ft
0.00 ft
N
1600
0
1600
Scale in Feet
Figure 11. Existing Conditions Water Depth
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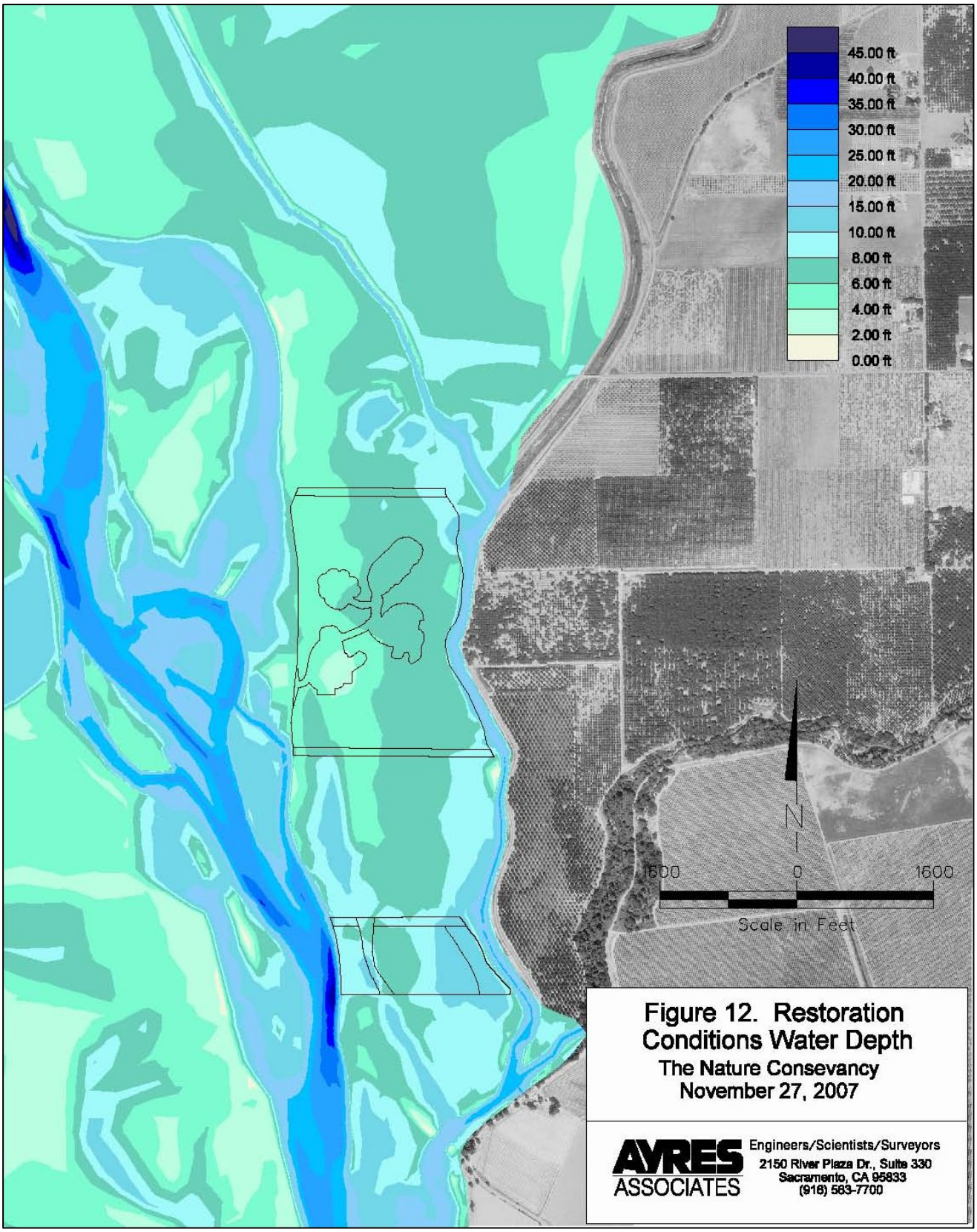

Figure 12. Restoration Conditions Water Depth
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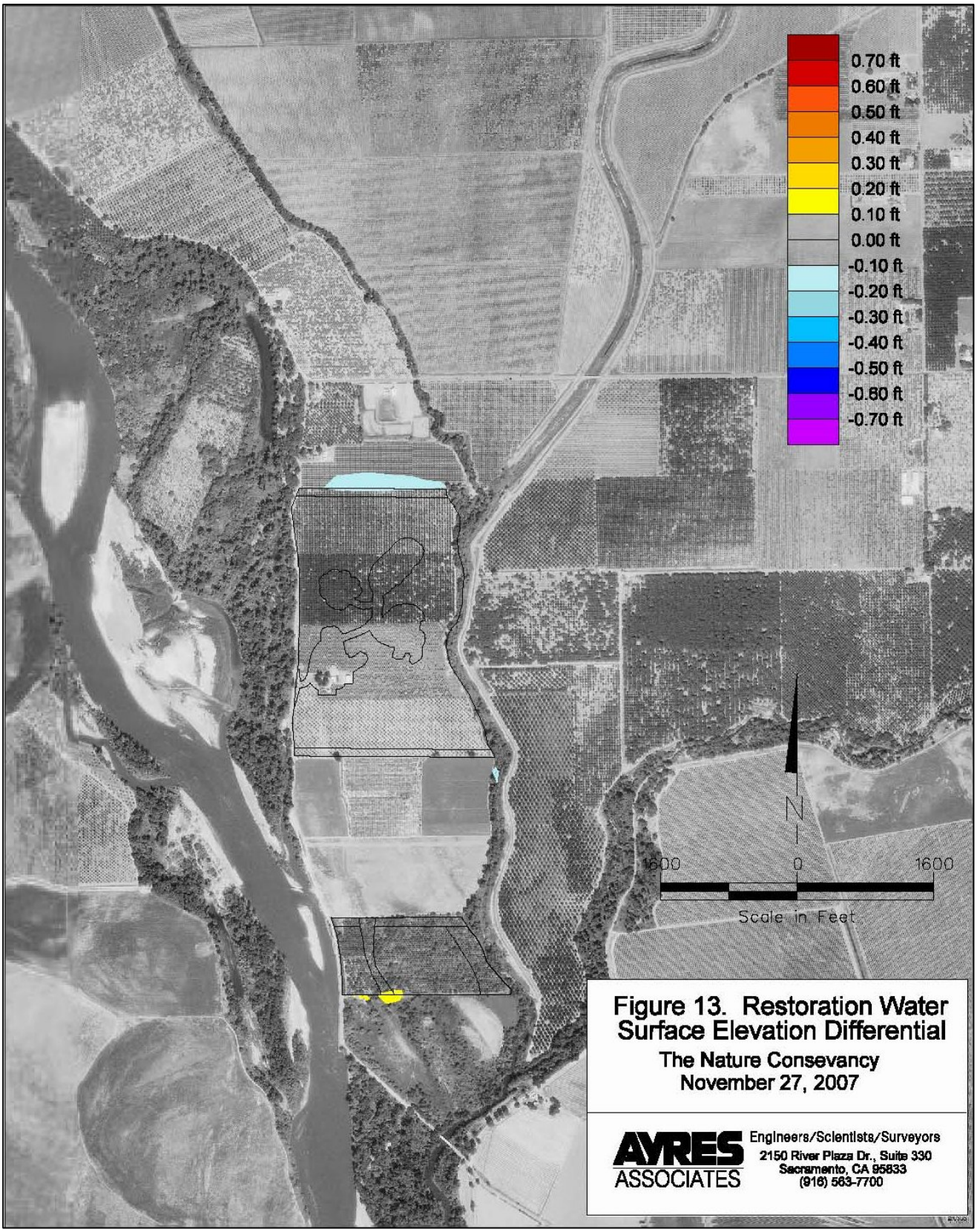
0.70 ft
0.60 ft
0.50 ft
0.40 ft
0.30 ft
0.20 ft
0.10 ft
0.00 ft
-0.10 ft
-0.20 ft
-0.30 ft
-0.40 ft
-0.50 ft
-0.60 ft
-0.70 ft
N
1600
0
1600
Scale in Feet
Figure 13. Restoration Water Surface Elevation Differential
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5.0 CONCLUSIONS

Based on the analysis performed and results presented in this report, we offer the following conclusions.

- The meadow flow-through in the Singh property causes a 2.5 ft/s increase, however given the low existing conditions velocities (1.0 fps) and planned vegetation, a resultant velocity of 3.5 fps should create no harmful effects at this location.

- The with-project condition model shows a slight increase in velocities in the campground area, grass buffers, and the locations of berm removals. These are considered less than significant and should cause no erosion problems.

- The hydraulic model shows some impact on water surface elevation. The maximum increase of water surface elevation is about 0.1ft at the southern boundary of the Singh Planting Zone.

6.0 REFERENCES

Ayres Associates, Two-Dimensional Hydraulic Modeling of The Upper Sacramento River, RM 194.0 To RM 202.0 Including Riparian Restoration, Two Setback Levee Alternatives, And East Levee Removal. Glenn and Butte Counties, California, 2002.

U.S. Department of Agriculture, 2006, Sacramento River Aerial Imagery